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NEWS OF FOREIGN SCIENCE AND TECHNOLOGY

CONSTRUCTION OF RESEARCH REACTORS IN ENGLAND

The atomic energy administration of the United Kingdom is building at Harwell two reactors, "Dido" and "Pluto", intended for broad investigations in physics and technology. Furthermore it is planned to construct a reactor of the "Pluto" type in Douneray. In addition, England is providing aid to Australia in the building of a "Dido" type reactor.

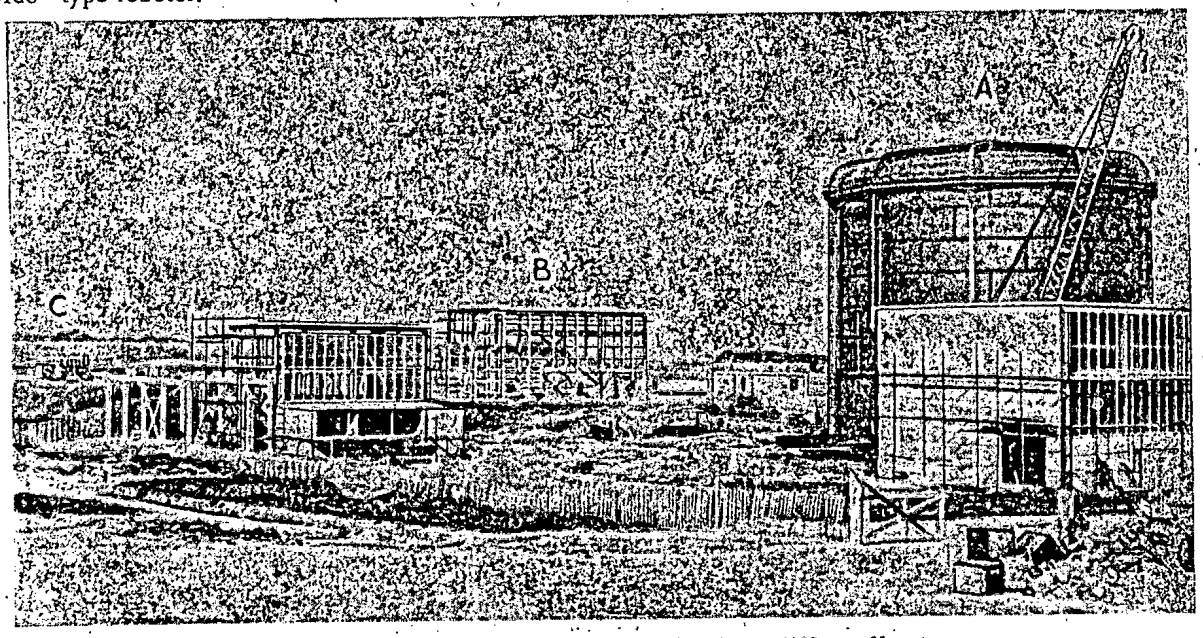

Fig. 1. Construction of new reactors for physical investigations at Harwell.
A) Reactor "Dido", designed for general physical investigations; B) construction of a reactor of the "basin" type, of 100 kw power and with neutron flux 10^{12} neutrons per cm^2/sec; C) reactor "Pluto", similar to the reactor "Dido", but designed for testing fuel elements.

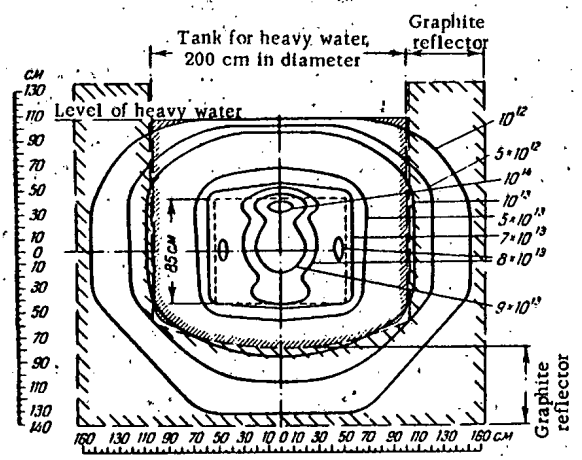

Fig. 2. Undisturbed distribution of thermal neutrons in the reactor "Dido" (all values in neutrons per cm^2/sec).

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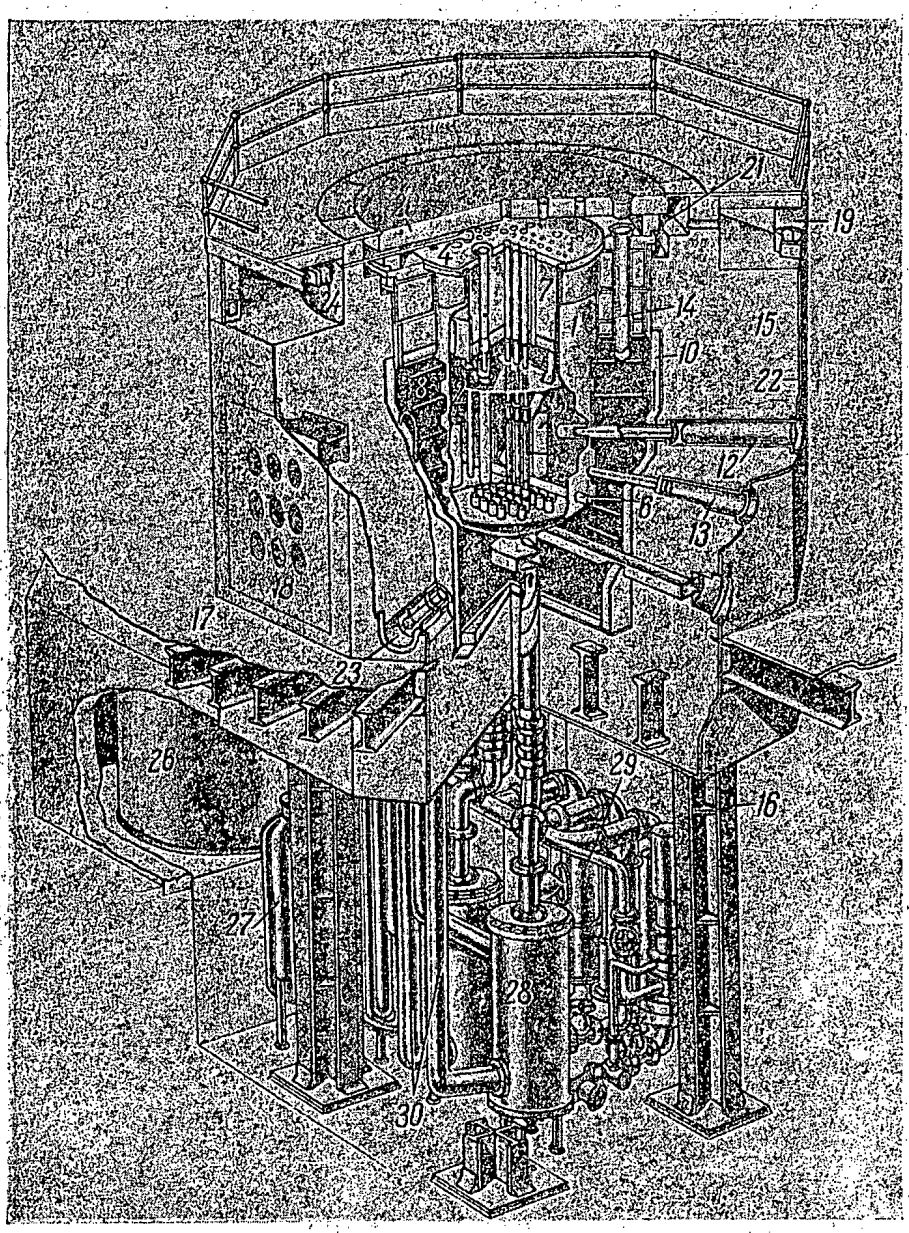

Fig. 3. 1) Aluminum tank for heavy water; 2) level of heavy water; 3) fuel element; 4) vertical experimental channel; 5) guides of six emergency rods; 6) experimental channel 10.16 x 5.08 cm; 7) biological shield; 8) graphite reflector; 9) experimental channels 30.48 x 20.32 cm; 10) lead heat shield (water cooled); 11) steel reactor vessel with boron covering; 12) experimental channel for taking neutrons from the active zone; 13) experimental channel for taking neutrons from the graphite reflector; 14) vertical channel from the graphite zone; 15) concrete shield; 16) supports of reactor; 17) first floor; 18) thermal column; 19) bracing of reactor foundation; 20) steel upper lid of thickness 25.4 cm; 21) experimental channel.

The "Dido" reactor is intended for use in physical experiments, for example the measurement of neutron cross sections, and the study of the parameters of various types of reactor lattices; besides this, the irradiation of small specimens of materials can be carried out in the reactor. The moderator and heat transfer agent of the reactor is heavy water, and the fuel is enriched uranium (about 6 kg, of which 2.5 kg is U^{235}).

The active zone of the reactor, with a volume of about 0.3 m^3, has the form of a cylinder of height 60 cm and diameter 86 cm. It is composed of lamellar fuel elements, whose filler is a mixture of uranium with

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aluminum. The active zone is located in the center of an aluminum tank of height 2 m and diameter 2 m. The reflector of the reactor is of graphite, 60 cm thick. The reactor and reflector are inclosed in a steel jacket filled with helium.

The nominal power of the reactor is 10 megawatts, with neutron flux 10^{14} neutrons per cm^2/sec. The maximum possible flux is $5 \cdot 10^{14}$ neutrons per cm^2/sec. The starting of the reactor is set for autumn, 1956.

At the end of 1957 the two reactors of the "Pluto" type are to go into operation. The construction and physical characteristics of these reactors are similar to those of the reactor "Dido", but their purpose is somewhat different; they are designed for the long-time testing of fuel elements. For this purpose it is planned to install six or eight testing loops in the reactor "Pluto".

I. S.

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A REACTOR WITH AN ORGANIC MODERATOR

According to reports there will be set in operation at the end of this year a reactor with an organic moderator (OMRE) with power 5 to 15 megawatts. The moderator used in the reactor is diphenyl, and the fuel is highly enriched uranium.

Preliminary experiments have shown the good stability of the organic moderator in the neutron field and insignificant deposition of precipitates (which had been feared earlier) in the form of a film on the surface of the fuel elements.

The reactor will probably be built by the Atomic Energy Commission, together with the "North American Aviation" Company in Arco, Idaho, U.S.A.

I. S.

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ECONOMIC INDICES OF ATOMIC STATIONS

Quite recently there have appeared in the American literature communications on the economic indices of certain reactors.

Admiral Rickover announced that upon the third loading of an active zone* of the reactor PWR at the Shippingport atomic station the cost of electrical energy will be lowered from 5.2 to 1.5 cents/kw-hr.

* In the reactor PWR it is planned to load successively the assemblies of different active zones.

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At the first loading of an active zone the cost of energy is composed of fixed expenditures (1.5 cents/kw-hr.) the cost of preparing fuel elements, the cost of zirconium and other construction materials (3.9 cents/kw-hr.) and operating costs (0.3 cent/kw-hr). From these 5.7 cents/kw-hr is subtracted the value of the processed fuel, equal to 0.5 cent per kw-hr.

At the second loading of an active zone the total cost of the energy will be reduced to 3.2 cents per kw-hr through the lower cost of fuel, a decrease of operating cost, and the increase of the power from 60 to 90 megawatts. At the third loading of an active zone the cost will be lowered to 1.5 cents/kw-hr. For the loading of the first active zone the working time of the reactor will be equivalent to 8000 hours of operation at full power, which means, including idle time of the reactor, more than one and one-half years. The exact working time with the first active zone is not known, since at first the reactor will be mainly used for experimental purposes. Its power will be increased gradually: 1st year, 10%; 2nd year, 20%; 3rd year, 40%; 4th year, 60%; 5th year, either 80% or full power.

The third loading of an active zone in the reactor will be accomplished not earlier than 1965.

The firm "Alco" has released formerly secret data on the cost of electric energy from the portable army reactor APPR, which is being constructed in Fort Belvoir (Virginia).

The fuel component of the cost of electrical energy will not exceed 0.95 cent/kr-hr. This sum includes: 0.6 cent/kw-hr cost of fuel calculated at 25 dollars per gram of U^{235}, 0.25 cent/kw-hr for preparation of fuel elements, and 0.1 cent/kw-hr for reprocessing. Operating expenses for an installation of power 2000 kw will amount to approximately 0.15 cent/kw-hr. Fixed costs will be 0.58 cent/kw-hr at load factor 80%.

Thus the cost of electrical energy will come to about 1.68 cents/kw-hr. The cost of energy from an analogous coal-burning station is 1.4 cents/kw-hr.

I. S.

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A PERFECTED METHOD OF FILM DOSIMETRY

The Oak Ridge Laboratory has developed a film dosimeter with which the following measurements can be carried out:

a) determination of dose and radiation energy of x-rays;
b) measurement of dose of γ-rays;
c) approximate determination of dose of β-rays acting alone;
d) approximate determination of dose of mixed β- and γ-rays.

For this purpose a system of filters is used to simplify the measurements and make them more exact.

An ideal filter for the measurement of a broad spectrum of x-rays is one with which the degree of blackening of the film depends only on the dose of radiation and not on the energy of the protons. Three types of filter are described in the report:

1. The filter consisting of the material of the cassette body, conventionally designed "OW" = "open window".

2. The "OW" filter plus 1.56 mm of cellulose acetate, called the "plastic" filter.

3. The filter of "OW" + 0.25 mm tungsten + 0.5 mm cadmium + 0.5 mm cellulose acetate, called the "shielding" filter.

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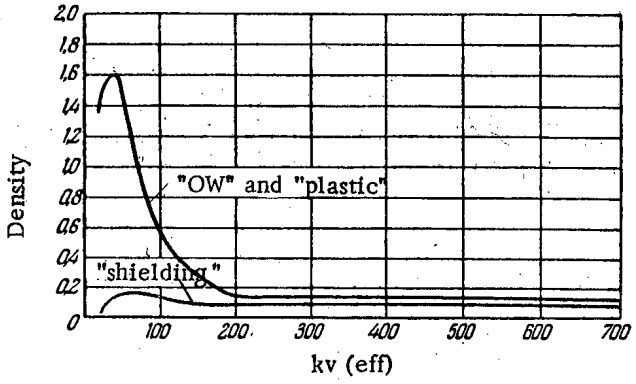

Fig. 1. Dependence of blackening density of film on energy of radiation (dose 200 mr). Upper curve with "OW" and "plastic" filters; lower curve with "shielding" filter.

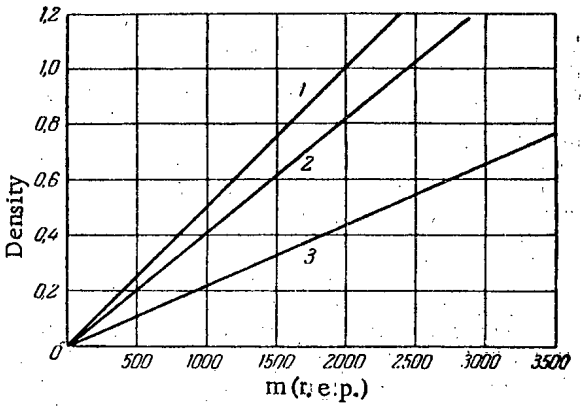

Fig. 2. Typical calibration curve for β- and γ-radiations with the different filters.
1) γ-Rays of radium, "plastic" filter; 2) γ-rays of radium, "shielding" filter; 3) β-rays of uranium, "OW" filter.

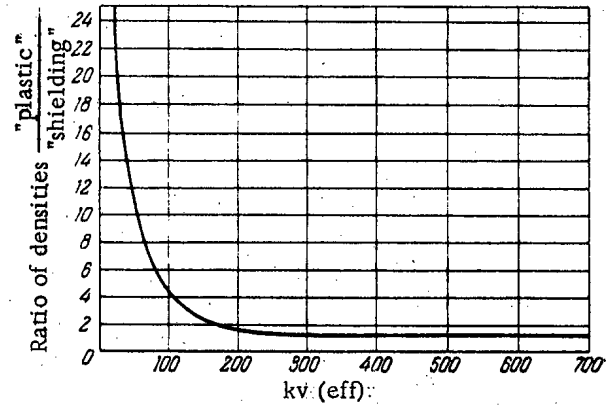

Fig. 3. Dependence of the ratio of the blackening densities for "plastic" and "shielding" filters on the energy of the radiation.

All three filters are placed side by side in one cassette so that each of them acts separately.

Fig. 1 shows a comparison of the blackening densities of the film with the "OW" and "shielding" filters for a 200 mr dose of radiation at various energies. The curves show that the blackening densities with the "OW" and "plastic" filters are equal. But for the action of β-particles the blackening under the "OW" filter is greater than under the "plastic" filter, and on this basis one can determine the dose of β-radiation in cases of mixed action of β- and γ-rays from the difference of the degrees of blackening.

The "OW" filter together with the film wrapper has thickness 80 mg/cm^2. β-rays of penetrating power 7 mg/cm^2 and over are considered harmful to human beings.

Figure 2 shows a typical calibrating curve for various radiations with the different filters. To determine the dose of β-radiation one needs only to multiply the difference of the readings with the "OW" and "plastic" filters by 1.5.

The dose of photons is determined in the following way:

1) from the calibration curve one finds the dose for γ-rays with the shielding filter;

2) by subtracting the density of blackening for β-rays from that for γ-rays with the "plastic" filter one finds a "correction" density, and then the dose corresponds to 1/10 of the "correction" density. The greater of the two doses found is taken as the dose of x- or γ-rays.

Although the determination of the dose of photons by the method described does not depend on the energy of the radiation, the filters make possible the determination of the energy of the radiation in effective kilovolts. This may be needed in case a knowledge of the relative "depth" of the dose is required. The determination of the energy of the radiation is made from the curve shown in Fig. 3, which gives the ratio of the degrees of blackening under the "OW" or the "plastic" filter to that under the "shielding" filter as a function of the energy of the photons.

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DOSIMETRY BY MEANS OF GLASS

The majority of existing methods of dosimetry, based on ionization measurements or on the calorimetric principle, do not provide speed, accuracy, and constancy of readings in the measurement of large doses. The changes of absorption for the visible spectrum of most sorts of glass when irradiated with doses of the order of 10^6-10^7 r.e.p. make it possible to use glass for the measurement of large doses of radiation. As a dosimeter glass has a number of advantages that make its use in this field very attractive. These are: chemical inertness, insolubility, small size, and durability. But there are a number of factors limiting the use of glass. The most important are low sensitivity, linearity of readings, and the rapid fading of glass at room temperature.

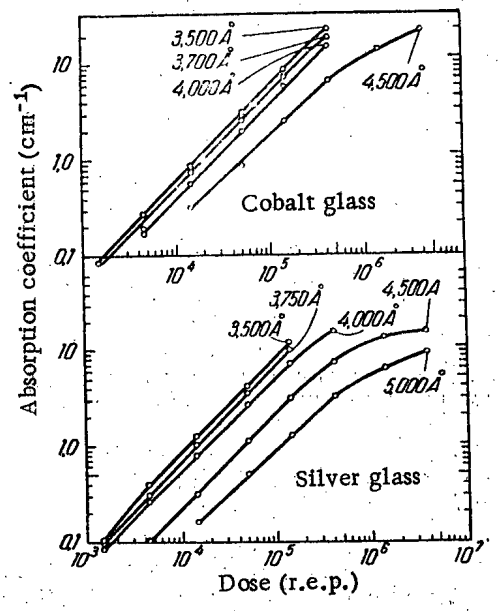

Fig. 1. Change of absorption of cobalt (upper curves) and silver (lower curves) glasses as functions of the dose of radiation.

In an investigation of these phenomena it was found that the addition to glass of elements such as cobalt and silver considerably increases the sensitivity of the glass to radiation and reduces the speed of its fading after irradiation. These types of glass have an absorption band for visible light in the part of the spectrum near the ultra-violet, and thus the investigation of their optical density was conducted with rays of wavelength from 3500 to 5000 A with a "Spectronic 20" colorimeter.

The paper gives data from tests of glass of the following chemical compositions: a phosphate glass, activated with silver: 50% $Al(PO_3)_3$, 25% $Ba(PO_3)_2$, 25% KPO_3, with 8% $AgPO_3$ added to this base; and a lime-silicate glass consisting of 70% SiO_2, 18% Na_2O, 10% CaO, 1% MgO, and 1% B_2O_3, activated by addition of 0.5% cobaltic oxide. For these types of glass, irradiated from a powerful source of Co^{60}, the calibration curves shown in Fig. 1 were constructed. From the curves it is seen that it is expedient to measure small doses in the short-wave part of the spectrum, and large doses with the longer waves. As is seen from the diagram, the cobalt glass has a change of its absorption coefficient after irradiation with a dose of $1.5 \cdot 10^4$ r.e.p. amounting to 0.54 for $\lambda = 4000$ A and 0.30 for $\lambda = 4500$ A. For doses from $5 \cdot 10^3$ to $4 \cdot 10^5$ r.e.p. the readings vary linearly. Above this limit the changes are smaller and nonlinear. But in the whole nonlinear part of the curve the changes of optical density with respect to the dose are well marked. The same dependence is also presented for the glass activated with silver.

It is known that the radiophotoluminescent reaction of silver glass does not depend on the energy of the radiation, if the energy exceeds 200 keV, but below this limit the reaction is stronger, reaching a maximum of 18:1 at 65 keV. Since the measurement of large doses is based on the very same process of absorption, it is very probable that the dependence of the absorption on the energy of the radiation is maintained. The authors calculated the absorption coefficients of the silver and cobalt glasses for three energies.

The paper of Davidson, Goldblith, and Proctor presents the data of an investigation of a phosphate glass activated with silver, which was subjected to the action of various physical agencies.

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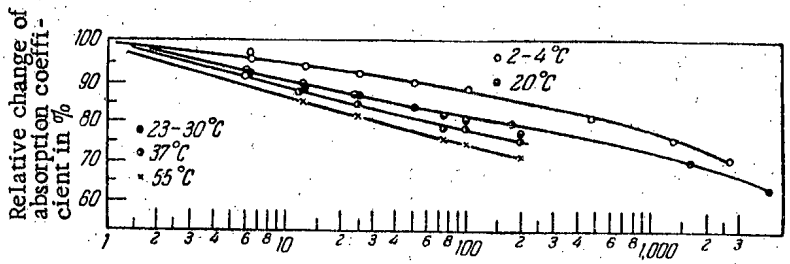

Fig. 2. Influence of storage temperature on irradiated glass that has not had heat treatment.

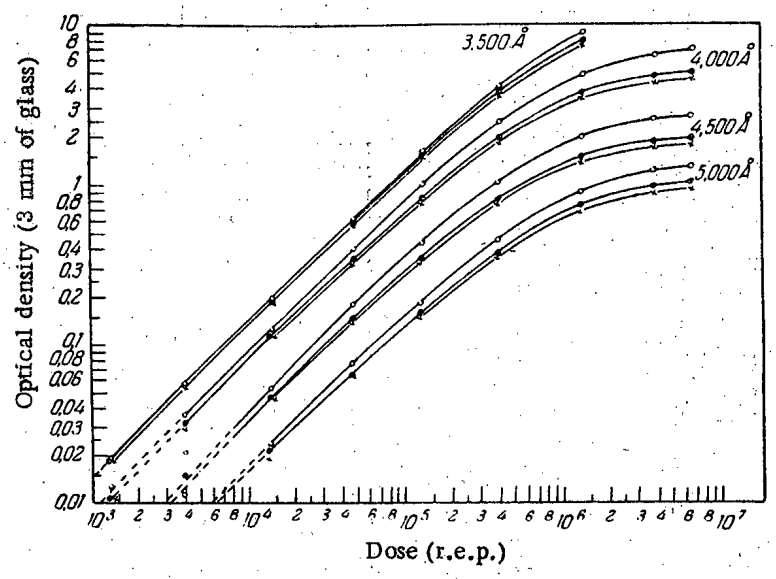

Fig. 3. Calibration curves for phosphate glass activated with silver. ○ An hour after irradiation; ◎ after heating for 10 minutes at 130°C; X after 8 days of storage at room temperature.

The source of radiation in the experiments described was a highly active preparation of Co^{60} with dosage power 1400 r.e.p./min. In some experiments a van de Graaf generator was used as a source of electrons with energy 3 Mev.

The optical density was measured by a Beckman spectrophotometer with a photomultiplier. The absorption coefficient was calculated by dividing the measured optical density by the thickness of the glass. The absorption in each glass was measured at four wavelengths: 3500, 4000, 4500, and 5000 A. The absorption coefficient referred to in this work is equal to the absorption coefficient of the irradiated glass minus that of the unirradiated glass.

For purposes of practical application of the method studies were made of some physical agencies influencing the readings given by the glass. Six pieces of glass, irradiated with a dose of $1.30 \cdot 10^5$ r.e.p. were kept under five different temperature conditions: room temperature (23-30°), refrigerator temperature (2-4°), and temperatures of 20, 37, and 55°. The pieces kept at 20 and 37° and at room temperature gave similar results in regard to fading. The low temperatures slowed down, and the high ones accelerated, the fading process in glasses that had not been subjected to the stabilizing action of heat (Fig. 2).

To determine the influence of high temperature on the optical readings of irradiated glass, pieces of glass were heated to temperatures of 130 and 150°C an hour after irradiation. The testing of pieces so treated

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was conducted at different intervals after irradiation, from 5 minutes to 8 days. The data from the tests showed that :

1) the absorption coefficient changes in inverse proportion to the elapsed time and to the temperature of the heating after irradiation;

2) the degree of fading during storage at room temperature is markedly decreased after the heat treatment;

3) the readings from pieces of glass that have had heat treatment are practically unaffected by the storage temperatures within the range from 2 to 43°C.

Fig. 3 shows calibration curves obtained by irradiation of glass with doses from $1.3 \cdot 10^3$ to $7 \cdot 10^6$ r.e.p., with subsequent heat treatment at 130° for 10 minutes. It is seen from the diagram that the slope of the curves is markedly reduced for doses exceeding $3 \cdot 10^5$ r.e.p., which indicates a decrease of sensitivity of the glass at such doses.

In the experiments described above the heat treatment was applied 1 to 1.5 hours after irradiation. In practice it is not always convenient to perform the heating at such an early time. Therefore a group of pieces of glass was heated at different time intervals after irradiation, and was then tested with the spectrophotometer. The tests showed that the absorption coefficient decreases almost linearly with the logarithm of the time for all intervals tried between irradiation and heat treatment, from 1 hour to 8 days.

In some cases irradiation at a low temperature can serve as a measure to decrease certain undesirable physical and chemical changes produced by irradiation. To study this matter, one group of pieces of glass was irradiated at room temperature, and another in ice water. The dose of radiation was $3.66 \cdot 10^5$ r.e.p. The chilled pieces of glass showed considerably less change of their optical readings. Thus the phosphate glass activated with silver can be used as a dosimeter at low temperatures, if the corresponding correction is made in constructing the calibration curves.

Preliminary tests have shown that irradiated glass can be bleached at temperatures of 400-500°. Further experiments will be conducted to determine how the sensitivity of the glass varies with repeated bleachings and how many bleachings can be used without damage to the accuracy of the readings. It was found that 15 minutes heating at a temperature of 450° is enough for complete bleaching of pieces of glass irradiated with doses up to $5 \cdot 10^6$ r.e.p. The sensitivity of pieces subjected to tens of repeated irradiations with bleaching after each irradiation was essentially unchanged. It follows that pieces of glass that have been irradiated once can be repeatedly used as dosimeters, which considerably increases their practical value.

The fact that the optical density of a large number of pieces of glass was measured under identical conditions made possible a statistical study of the results. The statistical study showed that the variations of optical density for pieces of glass from the same batch (melt) are inappreciable, so that the average values from measurements on several unirradiated pieces from a given batch suffice to give an idea of the optical density of all the pieces.

The study of pieces of glass irradiated with electrons of energy 3 MeV from a van de Graaf generator showed the possibility of using silver-activated phosphate glass for dosimetry of electron beams.

S. L.

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PRODUCTION OF GRAM QUANTITIES OF METALLIC PLUTONIUM

Buttons of plutonium weighing about 1 g have been produced by reducing plutonium trifluoride with calcium in an induction furnace with an atmosphere of argon (see diagram). The method for obtaining plutonium was previously developed with uranium; gram quantities of which were produced by reducing UF_4 with calcium. The starting material for the production of the PuF_3 was oxalate of plutonium (III). It was decomposed

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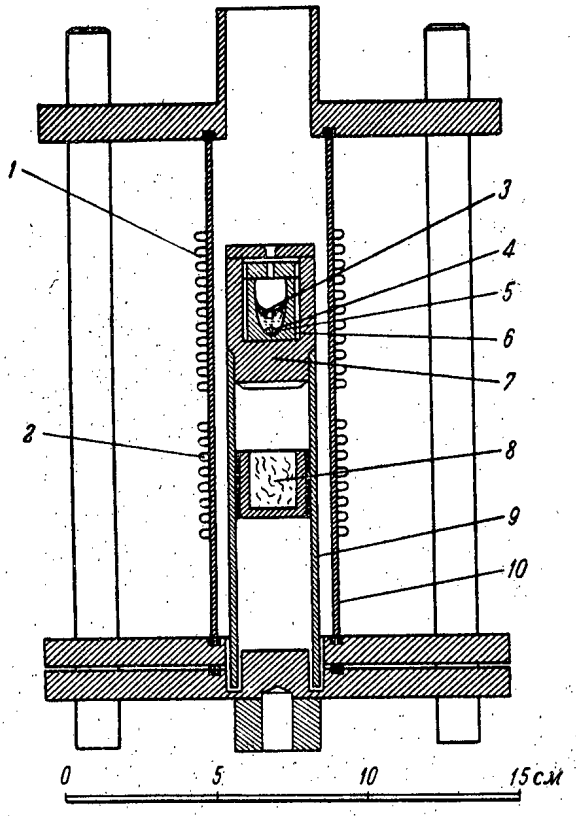
in a stream of air by the procedure: heating for 2.5 hours to 400°C and holding at this temperature for 0.5 hour. The plutonium dioxide so formed was fluoridized in a tube of monel metal by a (1:1) mixture of pure dry HF and H_2, by the reaction:

$$PuO_2+3HF+\frac{1}{2}H_2\xrightarrow[5\text{ hr}]{450^\circ C}PuF_3+2H_2O.$$



Induction furnace for smelting plutonium. 1) Circuit for heating crucible; 2) circuit for heating getter; 3) fluoride slag; 4) corrosion zone; 5) button of metal; 6) reaction crucible; 7) protective crucible; 8) getter (Ti–Zr chips); 9) quartz support; 10) quartz tube.

There was obtained a blue-violet trifluoride with composition: F–19.3%; Pu–80.1% (theoretical composition F–19.25%, Pu–80.7%).

Because of the great radioactive poisonousness of plutonium all of these operations were carried out in protective chambers filled with dry argon, in which were placed the furnaces and other apparatus.

The trifluoride was carefully mixed with fine chips of calcium (in 100% excess over stoichiometric quantity) and was placed in a calcium fluoride crucible, shaped parabolically in the used part to facilitate separation of the metal. The crucible was covered with a lid having a hole for observation of the flash at the start of the reaction, and was placed in the furnace, inside an outer protective crucible of calcium fluoride. The furnace was closed, evacuated, and washed out and filled with argon. Then for complete purification of the argon the getter was heated by the lower high-frequency circuit. The other circuit heated the crucible with its charge. The reaction began after several seconds, when the melting temperature of calcium was reached. After being continued for about a minute to allow reduction and separation of the metal, the heating was stopped. The excess calcium, mixing with the mass of fluoride slag, helped to heat it. If the heating were continued, there would be a fast reaction with the calcium fluoride crucible and it would melt. After cooling, the crucible was broken and the button of metal was removed from under the slag.

Despite the fact that the heat of reaction was considerably less than in the reduction of PuF_4, the reaction went through quite satisfactorily; the yield of metal was 85-90%.

Ya. P.

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